

Booster Beam Profile Measurements via Stripping Foil Losses

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Abstract

As demands on the Booster increase, so does the demand for obtaining beam profile measurements to improve diagnostics and reduce losses. Currently, wire studies remain the standard for these measurements, but this technique is destructive and requires dumping the beam prior to acceleration. We have developed a method to obtain profile measurements through losses from the stripping foil that may be used as a non-destructive, real-time beam profile monitoring system.

Method



Figure 1: Fast Loss Monitors used to detect losses. FLMs resolve losses of single RF buckets [1].

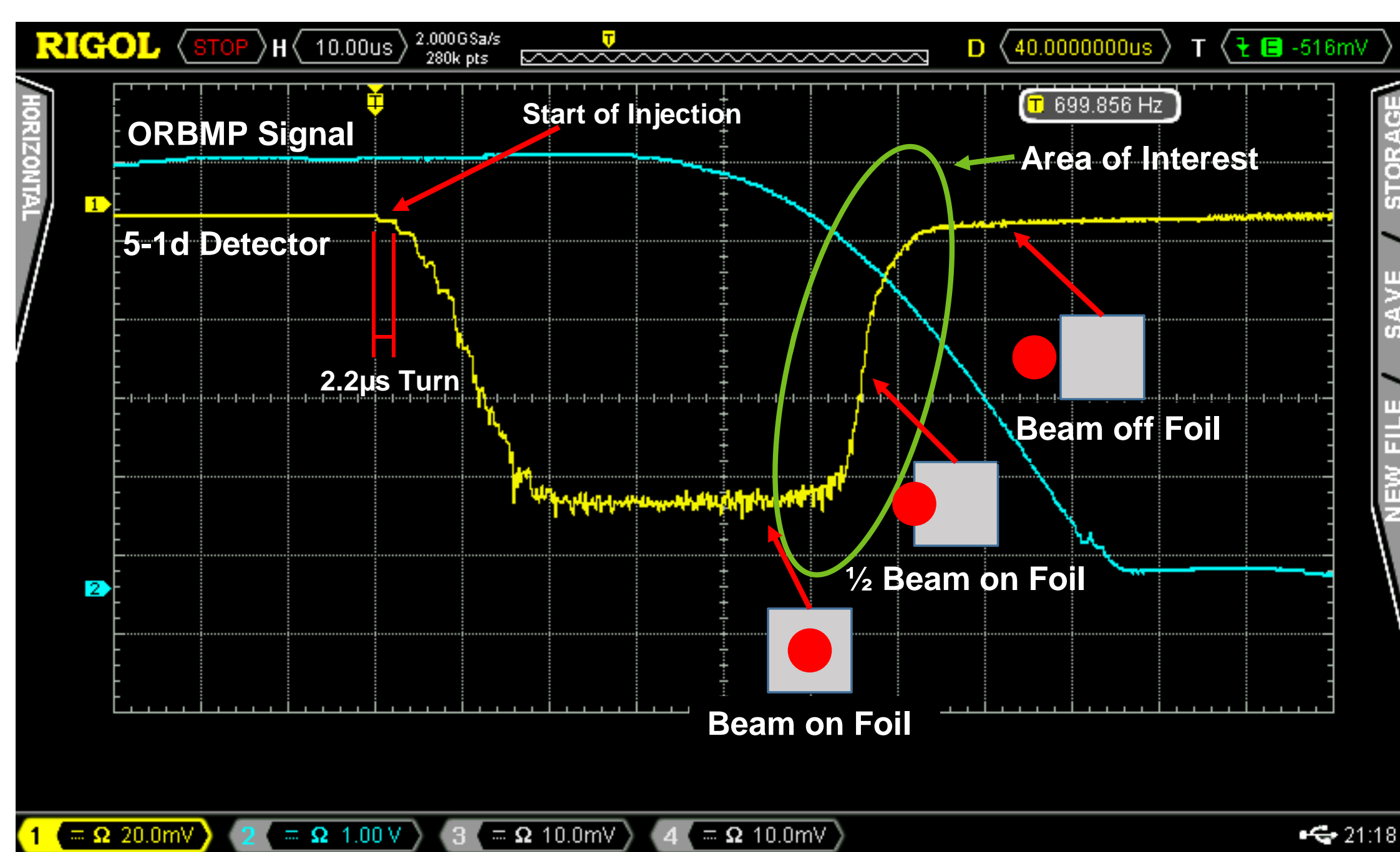


Figure 2: Oscilloscope trace with 5-1d detector and ORBMP signals.

As beam injected losses from the foil increase, ramping the ORBMP magnet down moves beam off the foil and decreases losses. The derivatives of the losses are related to the beam profile. Injection steps on the trace may be used to set normalization of the profile.

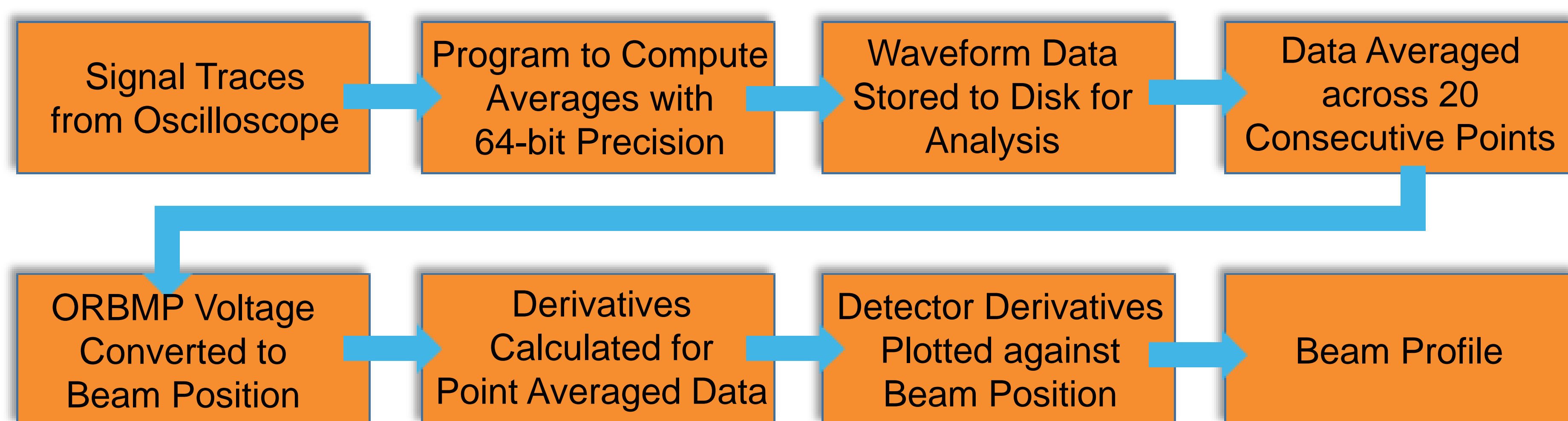


Figure 3: Method flow chart for calculating beam profile.

ORBMP voltage to beam position, where k is the calibration factor [2]:

$$\Delta x = \Delta V_{ORBMP} * k ; k = 6.23 \text{ mm/V}$$

Derivatives calculated as:

$$\frac{dy}{dx} = \frac{y_{n+1} - y_n}{x_{n+1} - x_n}$$

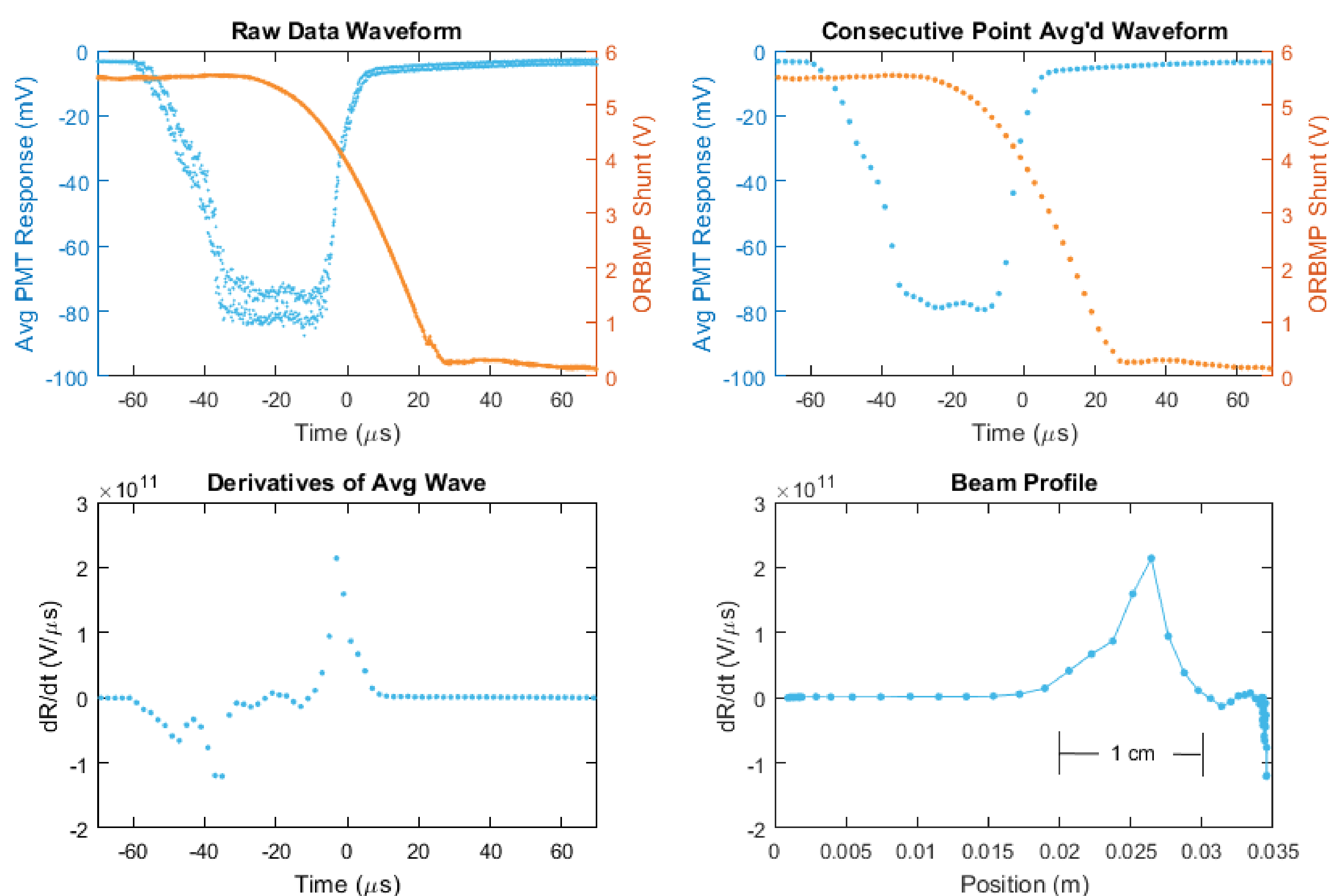


Figure 4: Graphs from ORBMP trigger trial; 256 traces in signal average.

Results and Analysis

We've established profiles can be made using this method, but how well do we understand these measurements under various conditions?

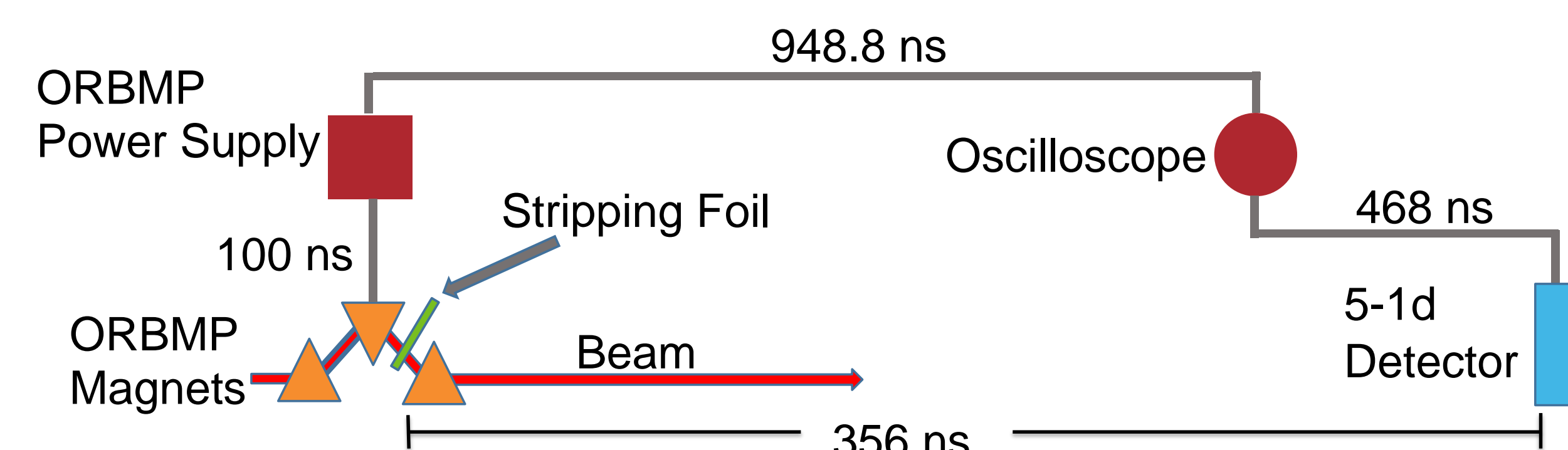


Figure 6: Diagram of test setup. Time-domain reflections were used to measure cable lengths.

Profile width values may depend on the relative timing of the ORBMP and counter signals (Fig. 6A). Cable lengths were measured and time of flight was calculated for 400 MeV protons. Operating conditions were kept within 100 ns.

We also check how measured beam width depends on:

1. Booster event types (BNB, NuMI)
2. Trigger on injections or ORBMP signal
3. # of traces in signal average
4. # of points in consecutive point averaging
5. ORBMP calibration factor

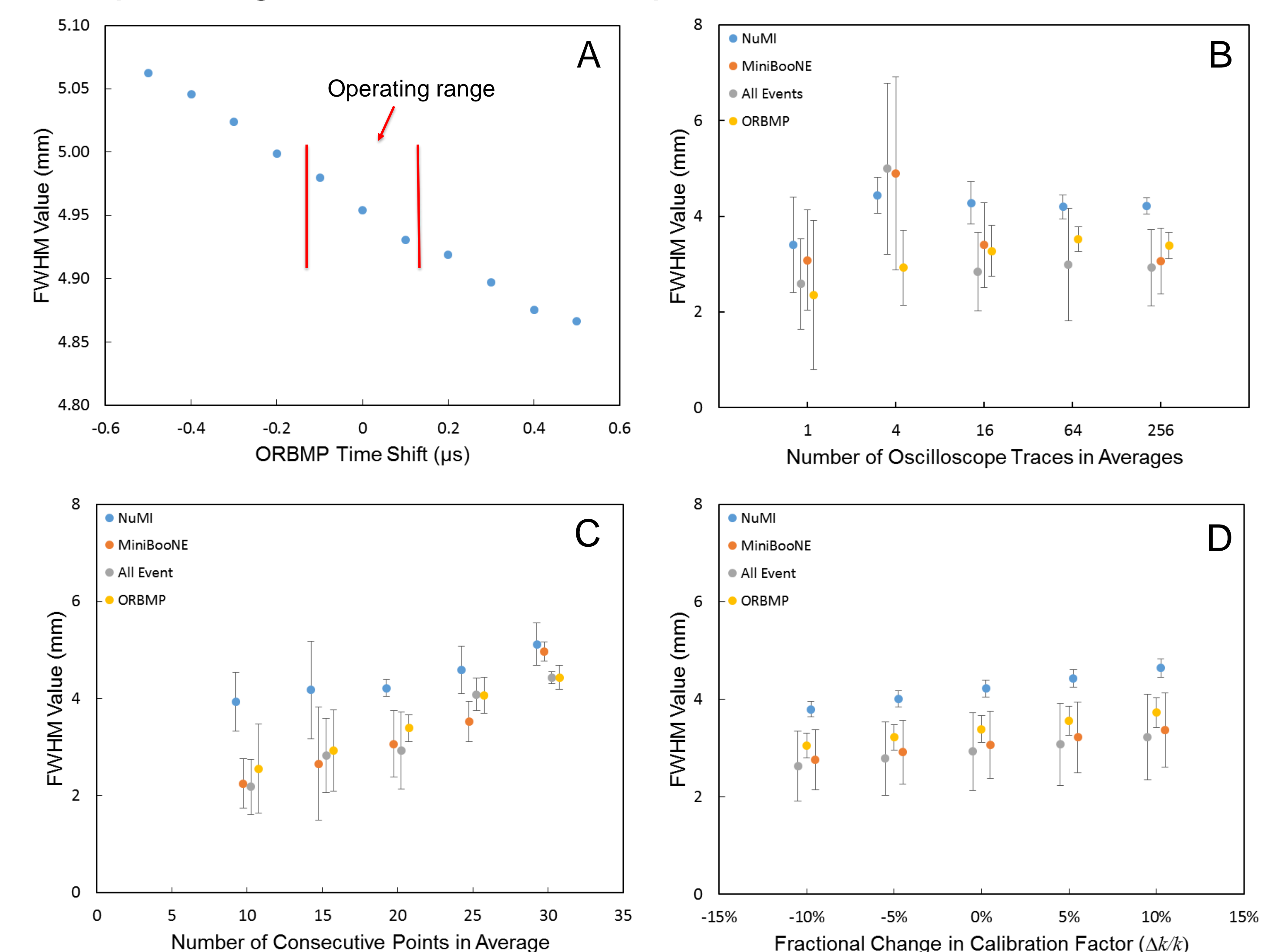


Figure 6: Beam widths under various conditions; values offset to distinguish error. Varying signal delay (A), "N" traces in waveform data (B), "N" points in consecutive average (C), changes in calibration factor (D). Expanded vertical scale in A to show systematic variation.

Conclusions and Next Steps

- The method developed in this study produces sensible beam profiles that are comparable to past studies.
- A wire study is needed to establish a base of comparison for width values.
- Dedicated electronics and optimization of detector placement could provide the control room with a new beam diagnostic tool, pending confirmation of measurements.
- Detectors used in this study degrade with radiation damage [3] and are past the end of their life cycle. Replacements will be installed during the summer shutdown.

References

- [1] Ornelas, C. "Booster Fast Loss Monitor Construction." Fermilab AD DocDB – 4993. August 7, 2015.
- [2] Tesarek, R. "A 'Non-Invasive' Beam Profile Measurement for the Booster." Fermilab AD DocDB – 5132. April 6, 2016.
- [3] Salinas, J. "Measuring Detector Radiation Damage." Fermilab Undergraduate Poster Session. August 11, 2016.